Optimization of DUNE Neutrino Beam-Line

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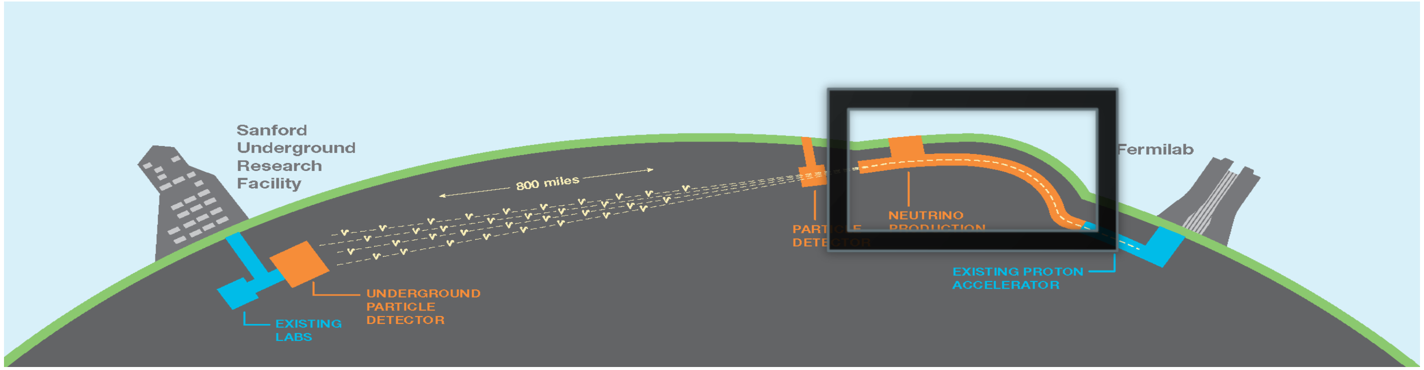
Overview

- Motivation of DUNE
- DUNE beam-line overview
- Beam-line optimization and goals
  - Horn focusing system
  - Decay pipe radius
- Conclusions
- Future work

Motivation of the Deep Underground Neutrino Experiment

DUNE is a high energy physics experiment that seeks to study neutrino oscillation, determine mass hierarchy, and discover CP violation.

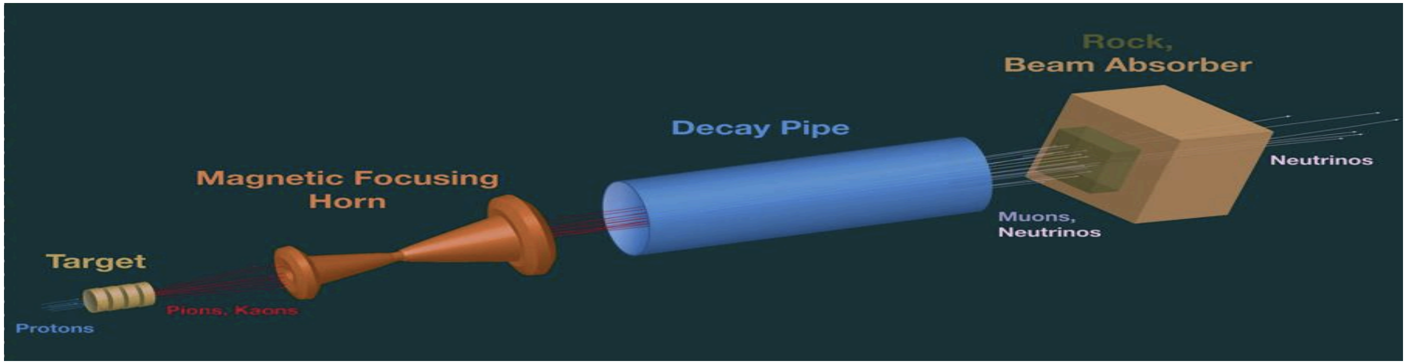
- Uses 1300km base-line with a 40kt LAr far detector in SURF
- Uses high intensity proton beams to increase neutrino flux
- Powerful detector technologies for near and far detectors



Closer look into the beam-line

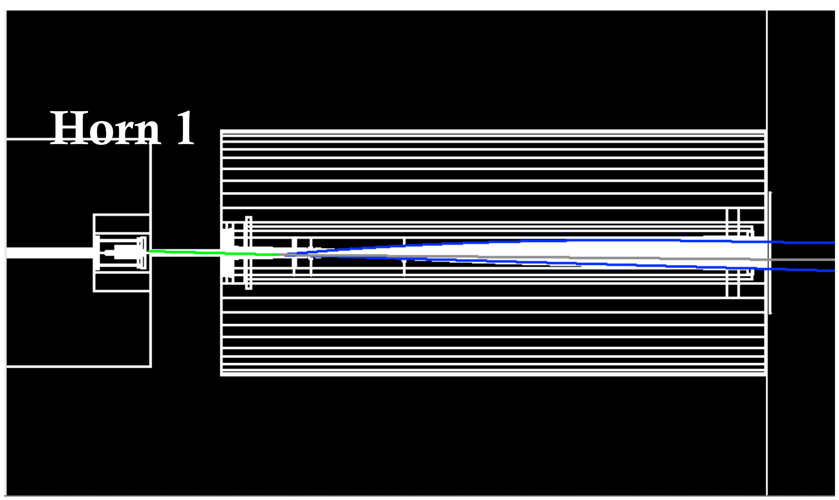
Standard geometry for the Neutrino beam-line:

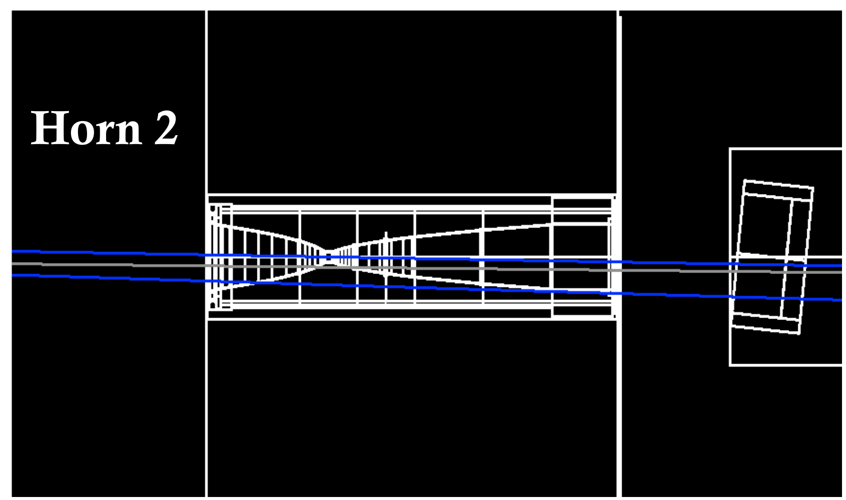
- Proton Accelerator
- Target
- Focusing Horn System
- Decay Pipe
- Beam Absorber



Nominal Horn Geometry

The current beam design, known as the "Nominal" geometry contains two NuMI-style horns.





Beam-Line Optimization Scheme

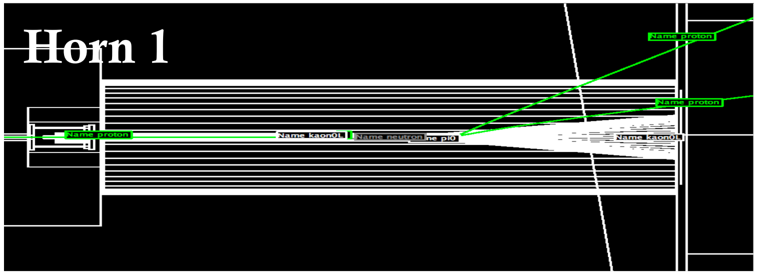
It is our goal to adjust certain aspects of the beam-line in order to optimize neutrino flux. Two of these have been studied in this presentation:

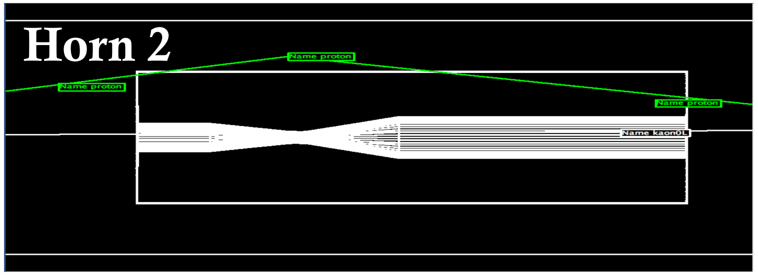
1. An alternate optimized horn geometry

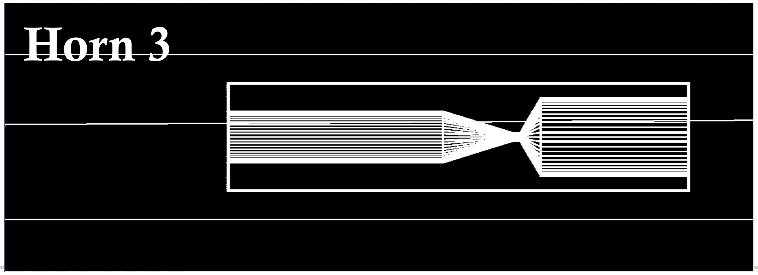
2. Modifying the radius of the decay pipe

Three Horn Optimized Geometry

- Description of Geometry:
  - Optimized three horn geometry

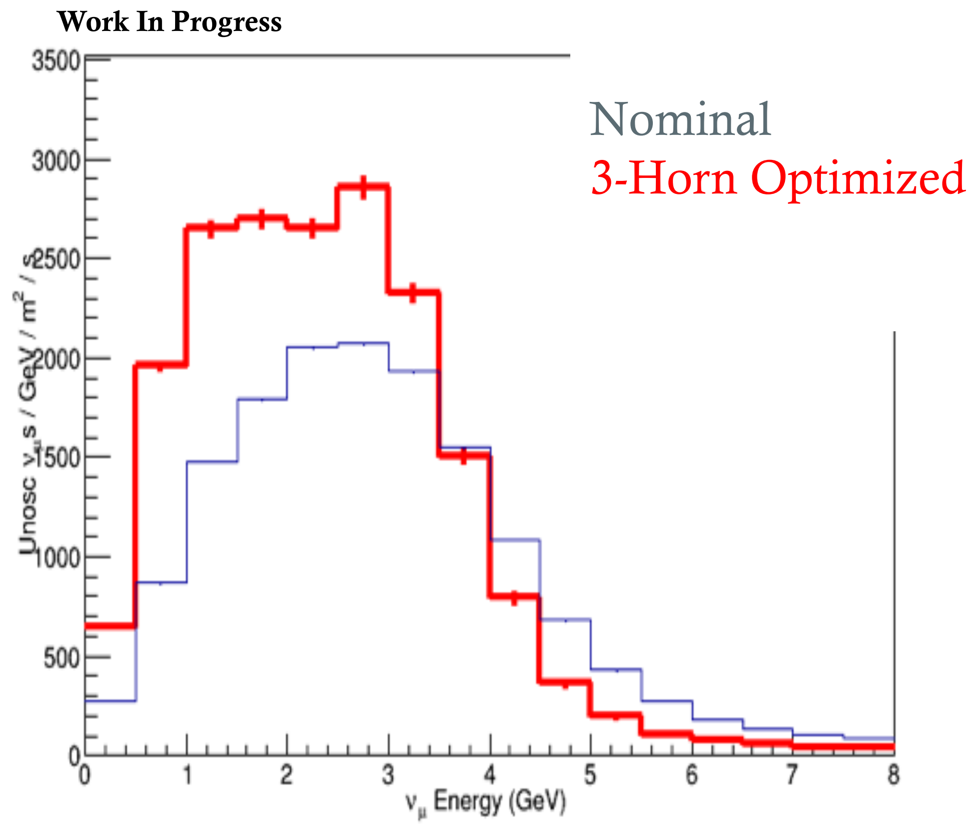






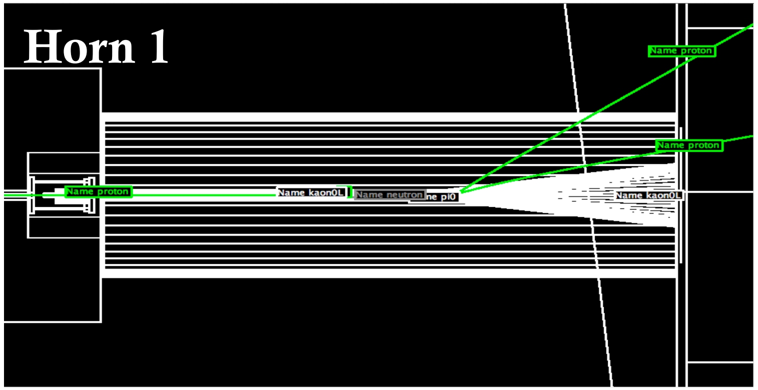
3 Horn -vs- Nominal

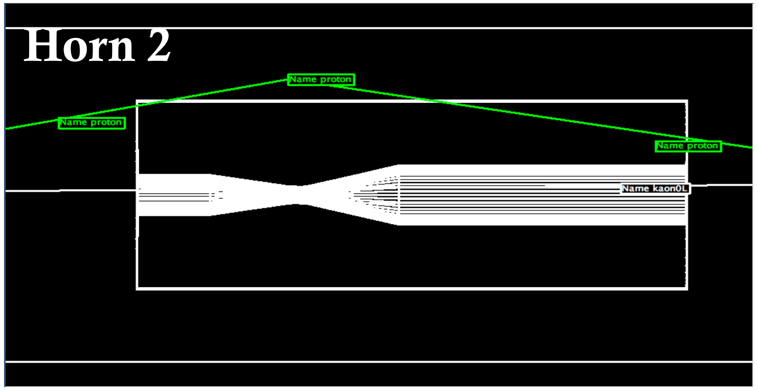
- Generated Neutrino flux is higher with the optimized three horn system
- What happens if the third horn is not ready at the start of the run?



Two Horn Optimized Geometry

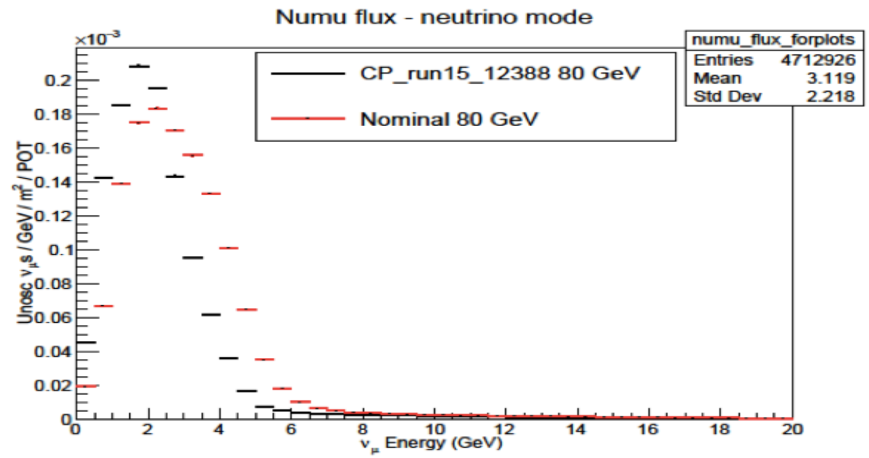
- Description of Geometry
  - contains the first two optimized focusing horns from optimized three horn geometry



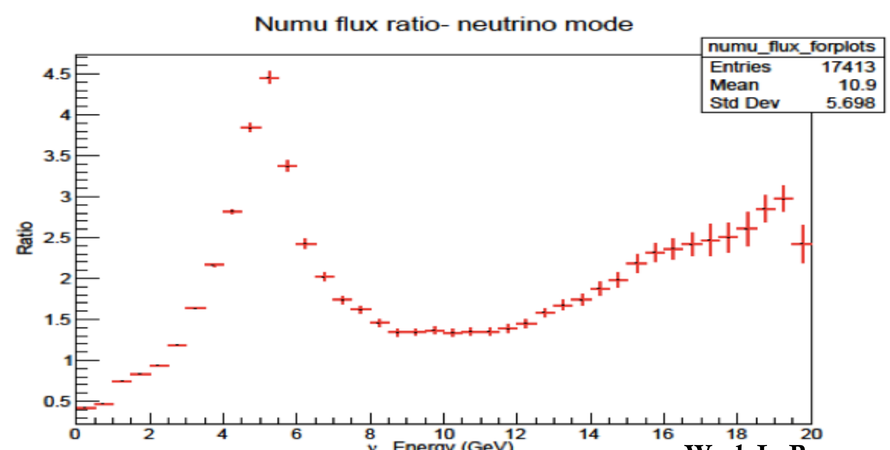


Optimized Two Horn –vs- Nominal

- With the optimized two-horn geometry, neutrino flux is observed to be higher at low energies, and lower in high energies
- The ratio plot reinforces this conclusion



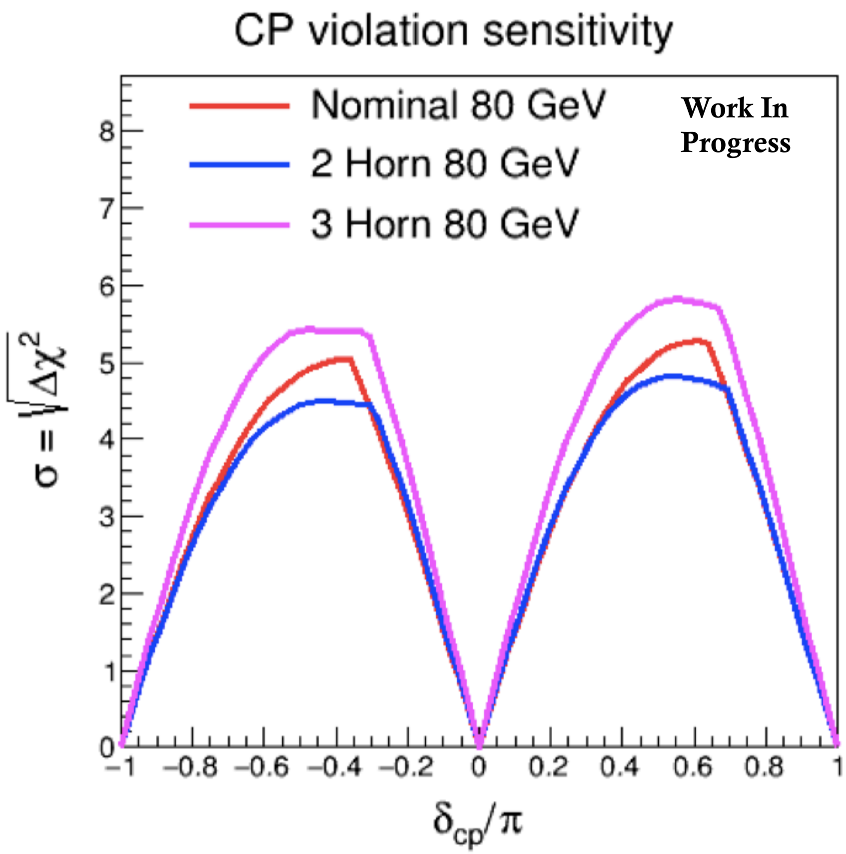
Work In Progress



Work In Progress

CP Violation Sensitivity

- The optimized three horn geometry has a higher CP violation sensitivity
- However, the two horn optimized geometry and the nominal geometry are nearly interchangeable

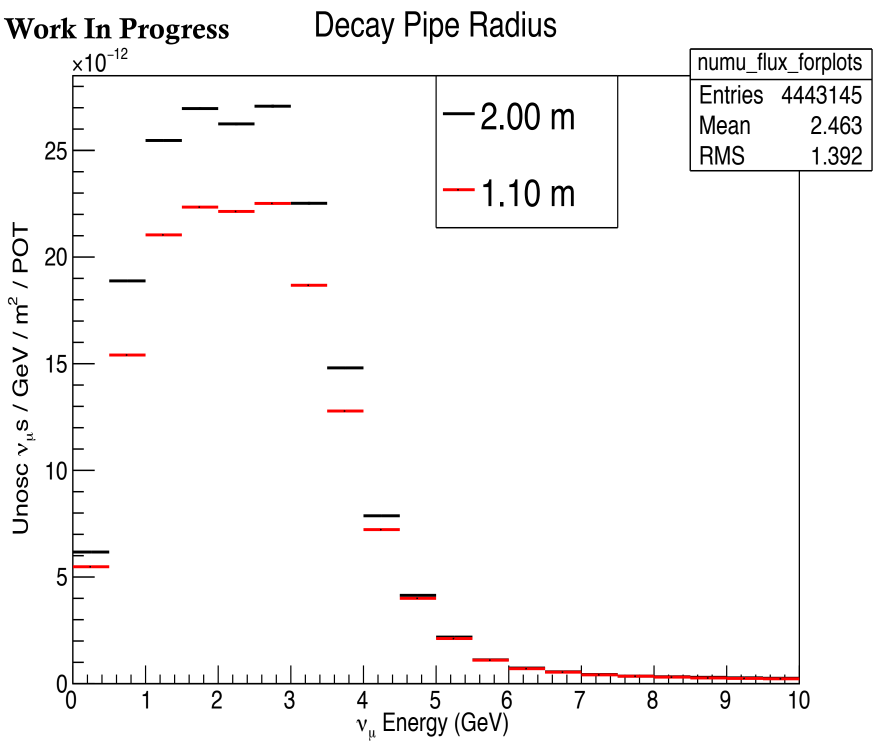


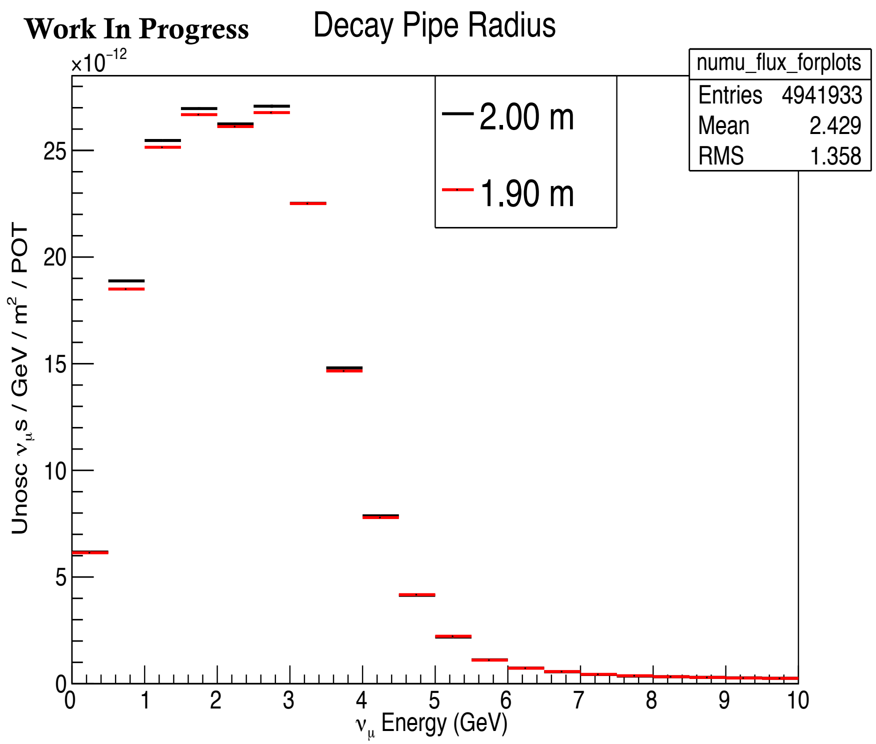
Optimization of Decay Pipe Radius

The goal is to find the optimal Decay Pipe radius for the optimized three horn design, and understand the relationship between the Decay Pipe itself and the generated flux.

- Decay Pipe was decreased by increments of 0.05 meters beginning at the standard of 2 meters
- Range covered parameters between 1.00 meter and 1.95 meters
- Neutrino Energy Range: 0.5 GeV to 4.5 GeV

Flux Comparisons

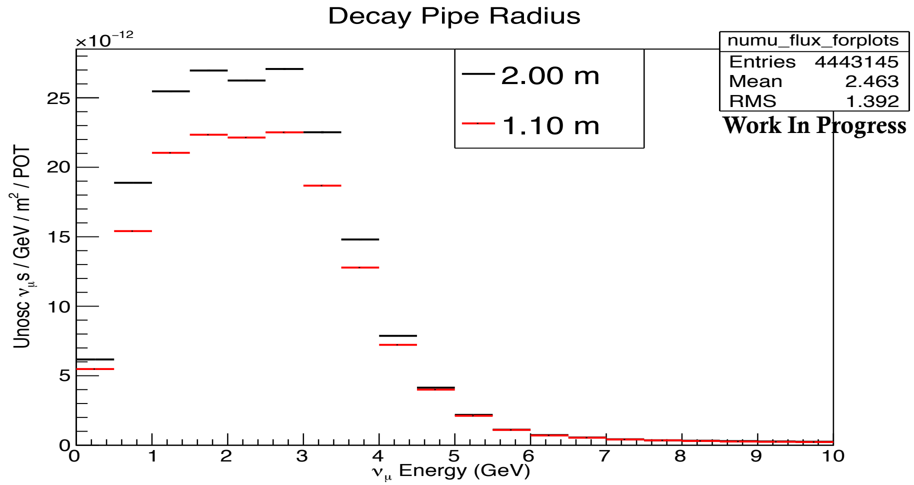


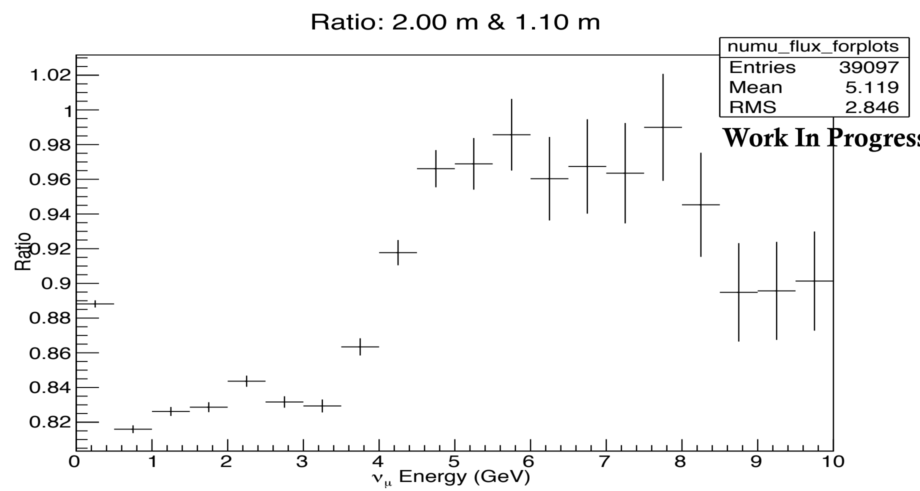


Flux Comparisons

- As radius increases, neutrino flux also increases towards the nominal values

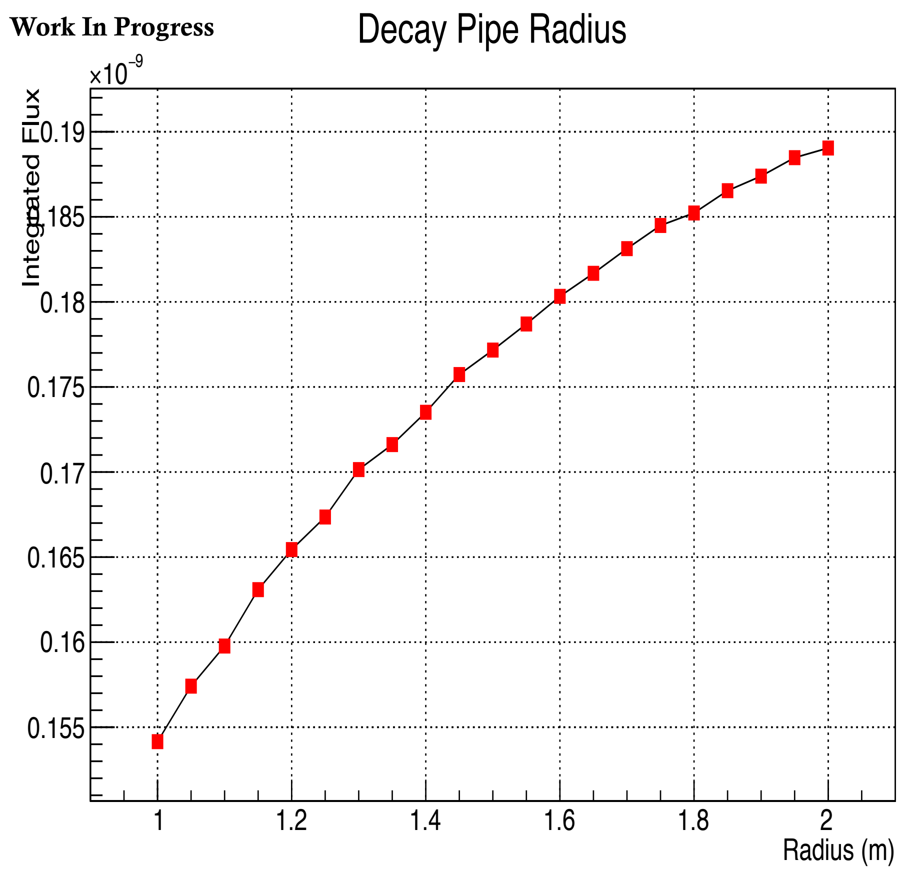
- Ratio plot shows the relative difference in flux





Flux vs Decay Pipe Radius

- The plot demonstrates the integrated flux as a function of radius
  - This is important as to understand how the radius affects generated flux



Conclusions

- The optimized three horn geometry is optimal, as it generates a high amount of neutrino flux and has a high CP Violation Sensitivity. However, if the third horn is not available then the optimized two horn geometry can be utilized without significantly affecting the physics.
- For our second study, the simulations demonstrate that the relationship between the generated flux and the Decay Pipe radius is proportional. Therefore, the 2 meter radius is optimal.
- Further detailed studies in CPV sensitivity for horn system optimization are on-going

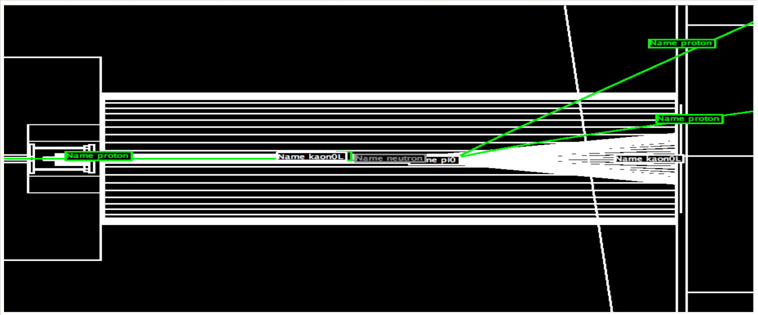
Future Work

- Compute CP violation sensitivity of all radii's of the Decay Pipe

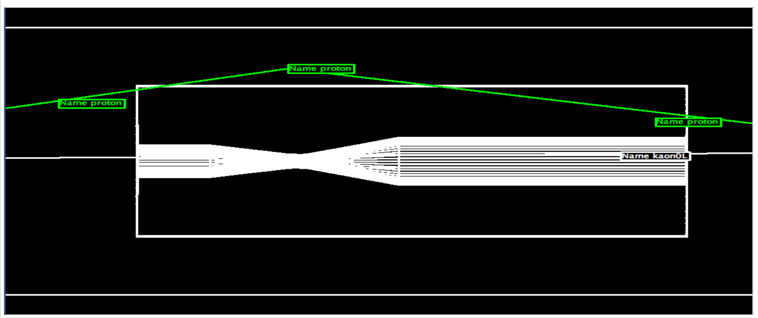
- Perform other similar studies of optimized beams under consideration by DUNE

Backup slides

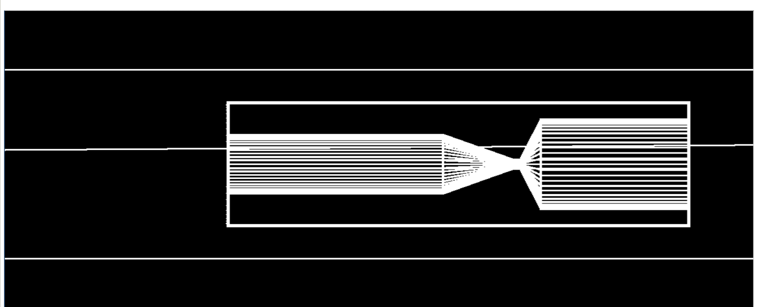
Three Horn Focusing System



Horn 1:
- located at right side of target area
- Length: 2817.97 mm
- Outer Conductor Radius 597 mm
- Inner Conducted Radius: 2 mm uniformly



Horn 2:
- Located 3636.6 mm along beam line
- Length: 3231.38 mm mm
- Outer Conductor Radius 630 mm
- Inner Conducted Radius: 2 mm uniformly



Horn 3:
- Located 17478 mm along beam line
- Length: 2818.75 mm
- Outer Conductor Radius 643 mm
- Inner Conducted Radius: 4 mm uniformly

Decay Pipe

- Decreasing to this radii would not compromise the data, neutrino flux does decrease but at a slow rate

Numu	Integral	Error	Percentage	Percentage Loss
1.0m	1.54E-10	1.59E-13	81.54	18.46
1.05m	1.57E-10	1.61E-13	83.27	16.73
1.10m	1.60E-10	1.62E-13	84.52	15.48
1.15m	1.63E-10	1.64E-13	86.27	13.73
1.20m	1.65E-10	1.65E-13	87.52	12.48
1.25m	1.67E-10	1.65E-13	88.53	11.47
1.30m	1.70E-10	1.67E-13	90.00	10
1.35m	1.72E-10	1.67E-13	90.78	9.22
1.40m	1.74E-10	1.68E-13	91.78	8.22
1.45m	1.76E-10	1.69E-13	92.96	7.04
1.50m	1.77E-10	1.69E-13	93.72	6.28
1.55m	1.79E-10	1.70E-13	94.53	5.47
1.60m	1.80E-10	1.70E-13	95.39	4.61
1.65m	1.82E-10	1.71E-13	96.10	3.9
1.70m	1.83E-10	1.72E-13	96.87	3.13
1.75m	1.84E-10	1.72E-13	97.59	2.41
1.80m	1.85E-10	1.72E-13	97.98	2.02
1.85m	1.87E-10	1.73E-13	98.67	1.33
1.90m	1.87E-10	1.73E-13	99.13	0.87
1.95m	1.88E-10	1.74E-13	99.70	0.3
2.0m	1.89E-10	1.73E-13	100	0